Measuring θ_{13} with Reactor Antineutrinos at Daya Bay

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Recent experimental results indicate that neutrinos have a small but finite mass and change flavor. The phenomenon of neutrino mixing is characterized by the coupling between the flavor and mass eigenstates and the associated mixing angles (θ_{12}, θ_{23}, θ_{13}). Previous neutrino oscillation experiments, including SNO and KamLAND, have determined two of the three mixing angles in the neutrino mixing matrix, U_{MNSP}. The mixing angle θ_{13}, however, is yet unknown.

The current best upper limit on θ_{13} comes from the CHOOZ reactor neutrino disappearance experiment [1]. It shows that θ_{13} is small compared to the large mixing angle observed in solar neutrino oscillation and the nearly maximal mixing in atmospheric neutrinos. A next-generation reactor experiment will allow the measurement of θ_{13} with no ambiguities due to matter effects and better precision than other proposed experiments. With a proposed sensitivity of $\sin^2 2\theta_{13} \leq 0.01$ future reactor neutrino experiments will complete our understanding of the neutrino mixing matrix and determine whether the search for CP-violation in neutrinos is feasible at future accelerator facilities.

Next-generation reactor experiments plan to use the flux of $\overline{\nu}_e$ produced in fission power plants and measure the rate and energy spectrum of $\overline{\nu}_e$ interactions at different distances from the reactor to make a precise measurement of θ_{13} at the level of $\mathcal{O}(1\%)$. These experiments require the construction of underground detector halls and access tunnels for the placement of several 50-t liquid scintillator detectors in the vicinity of a nuclear power plant. Overburden in excess of several hundred meters water equivalent (mwe) is required to reduce cosmic-ray related backgrounds. The relatively fast timescale and the modest project cost make the measurement of θ_{13} with reactor neutrinos particularly attractive.

FIG. 1: Photograph of the LingAo plant near Daya Bay.

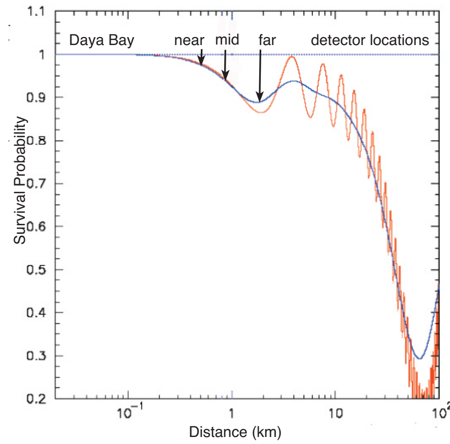

FIG. 2: Using multiple detectors placed at distances of 0.2-2.0 km from the core a future reactor neutrino experiment can make a precise measurement of neutrino oscillation associated with θ_{13} from a relative measurement of the $\overline{\nu}_e$ rate and energy spectrum.

Over the course of the past year the Daya Bay θ_{13} collaboration has performed design and engineering studies towards a future reactor neutrino experiment at the Daya Bay nuclear power plant in China near Hong Kong [2]. The Daya Bay-Ling Ao complex consists of 4 reactor cores with a total thermal power of 11.7 GW. Nearby coastal mountains provide up to 1200 mwe overburden. Specific contributions of the Berkeley group include detector performance simulations, mechanical engineering design studies of the detector system, and conceptual design work on the electronics, muon veto system, and calibration devices. The Daya Bay proto-collaboration currently consists of about 70 scientists from the US, China, and Russia.

In the past year we held two collaboration meetings, one in Berkeley in December 2004 and one in Hong Kong in January 2005. Recently, US collaborators submitted a proposal for US participation in the Daya Bay reactor θ_{13} experiment to the Neutrino Science Assessment Group (NuSAG) for review.

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[1] M. Apollonio et al., Eur.Phys.J.C27:331-374 (2003)
[2] http://theta13.lbl.gov/